

## Description

# Gas Dynamic Pressure Bearing Unit, Spindle Motor, Hard Disk Drive and Polygon Scanner Utilizing Gas Dynamic Pressure Bearing System

### BACKGROUND OF INVENTION

### FIELD OF THE INVENTION

[0001] The present invention relates to a gas dynamic pressure bearing system. The invention also relates to a spindle motor, a data storage disk drive and a polygon scanner using the gas dynamic pressure bearing system.

### DESCRIPTION OF THE BACKGROUND ART

[0002] In recent years, it has increasingly been required to enhance the speed of access to information in a hard disk drive or an optical disk drive, and to enhance printing quality and speed in a digital copier and a laser printer. To meet the requirements, the precision and rotation speed of the spindle motor used in such machines is enhanced.

Spindle motors with higher precision are also required for those machines.

[0003] To enhance the precision and rotation speed of the spindle motor, it is proposed to use the gas dynamic pressure bearing system as a bearing system of the spindle motor. The gas dynamic pressure bearing system supports a rotating member in a non-contact manner, when the rotating member is rotating, by a dynamic pressure of gas filled in a minute gap formed between members.

[0004] In the gas dynamic pressure bearing system, however, at the moment of start or stop rotating, bearing surfaces come into contact with each other, and abrasion particles are formed by wearing. Such abrasion particles are accumulated in a gap of the thrust bearing, and will eventually enter a minute gap of a radial bearing. The gap between bearing surfaces of the radial bearing is smaller than those of the thrust bearing, and the radial bearing surfaces are prone to be damaged by the abrasion particles. Some portion of the abrasion particles could escape from the bearing system and contaminates a disk chamber. Such situation causes a reading error or a writing error of data of the disk, and a magnetic heads or recording surfaces of the disk is damaged.

[0005] Some prior bearing systems have a circulation passage, which comprises an additional through-hole connecting the both end portions of the bearing gap, for the lubricant gas to circulate in the bearing. Although a portion of the dust particles is trapped on the way through the through-hole, the rigidity of the bearing system is not sufficient because the pressure of the lubricant gas decreased through the through-hole.

[0006] Thus, there is a need in the art for a gas dynamic bearing system design which is capable of providing sufficient rigidity together with a particle trap mechanism.

#### **SUMMARY OF INVENTION**

[0007] The present invention is a result of seeking a novel gas dynamic pressure bearing system in which abrasion particles generated by sliding motion of bearing surfaces are prevented from damaging the interior of the bearing system, while the rigidity of the bearing is kept sufficient.

[0008] In the gas dynamic pressure bearing system of the present invention, the thrust bearing increases a gas pressure toward the radial bearing. The radial bearing increases gas pressure toward the thrust bearing. With these two effects, a high pressure is applied to gas filled in the bearing gap in the vicinity of annular micro-gap portion be-

tween the gap of the thrust bearing and the gap of the radial bearing. In such a state, a dynamic pressure generated by rotation of the shaft is high, which support the shaft rigidly. As a result, the gas dynamic pressure bearing system exhibits high rigidity without narrowing the bearing gap.

[0009] Abrasion particles are generated when the bearing system starts rotating and stops rotating during which the bearing surface comes into direct contact. Since the gap of the bearing surface is especially small at the radial bearing gap, if the abrasion particles enter into the radial bearing gap, the radial bearing surface is damaged, and the bearing rotates abnormally. Thus, some devices are needed to prevent the abrasion particles from entering the radial bearing gap.

[0010] At the time of rated rotation, the radial bearing imparts on the oil greater pressure acting toward the thrust bearing than that the thrust bearing imparts acting toward the radial bearing. So the very few abrasion particles enter the radial bearing gap in this state, and the particles are accumulated between thrust bearing surfaces or at their outer peripheral portions.

[0011] However, when the bearing starts rotating or stops rotat-

ing, there is a risk that abrasion particles enter the radial bearing gap, since the radial bearing generates the weaker pressure and the particles between the thrust bearing surfaces tend to be carried by the dynamic-pressure-generating groove row.

[0012] Thereupon, in the present invention, a portion of the dynamic-pressure-generating groove of the thrust bearing is extended to form the particle catching hole. Since the dynamic-pressure-generating groove and the hole for catching particles are continuously formed, abrasion particles enter the hole with high probability, and the particles are retained in the hole.

[0013] With such a configuration, the lifetime of the bearing system is increased, and the reliability is enhanced. In addition, this bearing system is suitable for usage which requires cleanness such as a hard disk drive, since the particles are trapped in the particle catching hole.

[0014] The hole for catching the particles may be formed by directly forming a hole in an outer peripheral surface of the shaft.

[0015] There are other methods to form holes to the shaft. One of the methods comprises two steps. First, one or more grooves are formed on the axial face of the shaft, the di-

ameter of which is larger at axially central portion and smaller at the both end portion, forming steps between the end and central portion, the steps extending radial direction. Second, the grooves on the step are covered by the face of the thrust plate and the grooves become holes, while the inner end of the grooves on the thrust plate is to be aligned to match the outer end of the grooves on the step. The process to carve grooves on the step face can be eliminated. In the case, one or more grooves on the thrust plate is extended inwardly and the extended portions are covered by the step face.

[0016] Those alternative methods are suitable when the material of the shaft is very hard to be drilled, reducing the machining costs.

[0017] In the gas dynamic pressure bearing system of the present invention, bearing loss at the time of high speed rotation is small. Therefore, if this gas dynamic pressure bearing system is utilized in a spindle motor for driving a disk which records a signal such as a hard disk or a super-fast optical disk, a preferable result can be obtained.

[0018] Similarly, this bearing system can be suitably used for a polygon mirror scanner which needs to rotate at extremely high speeds.

[0019] Since the amount of particles leaking from the bearing system is small, if the bearing system is applied to a spindle motor for a hard disk, the possibility that the disk surface is contaminated by particles is lowered, and the reliability thereof is enhanced.

#### **BRIEF DESCRIPTION OF DRAWINGS**

[0020] Fig. 1 is a sectional view of a gas dynamic pressure bearing system according to the present invention;

[0021] Fig. 2 is an enlarged sectional view 1 of the gas dynamic pressure bearing system of the invention in the vicinity of a particle-catching hole;

[0022] Fig. 3 is an enlarged sectional view 2 of the gas dynamic pressure bearing system of the invention in the vicinity of the particle-catching hole;

[0023] Fig. 4 is an enlarged sectional view 3 of the gas dynamic pressure bearing system of the invention in the vicinity of the particle-catching hole;

[0024] Fig. 5 is a plan view of a groove pattern formed on a thrust plate surface;

[0025] Fig. 6 is a plan view of the groove patterns formed on the thrust plate surface and an outer shaft end;

[0026] Fig. 7 is a sectional view of a spindle motor according to the invention;

[0027] Fig. 8 is a sectional view of a data storage disk drive according to the invention; and

[0028] Fig. 9 is a sectional view of a polygon scanner according to the invention.

## **DETAILED DESCRIPTION**

### **FIRST EMBODIMENT**

[0029] A first embodiment of the present invention will be explained using Figs. 1, 2 and 5.

[0030] A gas dynamic pressure bearing system 9 shown in Fig. 1 includes a stationary part 1 and a rotary part 2. The radial bearing 3 and the thrust bearing 4 rotatably supports the rotary part 2 such that the rotary part 2 can rotate with respect to the stationary part 1.

[0031] The stationary part 1 comprises a shaft 14 and two thrust plates 15 separated away from each other in an axial direction of the shaft 14. A surface of each the thrust plate 15 radially spreads, constituting a flat surface of the stationary part, and a thrust bearing surface 13 is formed thereon.

[0032] The shaft 14 comprises an inner shaft 14a and an outer shaft 14b which is fitted over the inner shaft 14a. By mounting the outer shaft 14b, the shaft is formed with a



columnar enlarged portion. An outer peripheral surface of the enlarged portion is a radial bearing surface 11. A lower surface of the thrust plate 15 is the thrust bearing surface 13.

[0033] The rotary part 2 includes a sleeve 24 and a hub 62 which is fitted over the sleeve 24. The sleeve 24 is a hollow cylindrical shape having a hole which penetrates the sleeve 24 in an axial direction thereof. An inner peripheral surface of the sleeve 24 is a radial bearing surface 21. An axial end surface of the sleeve spreads in its radial direction, constituting a flat surface of the rotary part, and a thrust bearing surface 23 is formed thereon.

[0034] The radial bearing surface 11 of the stationary part 1 and the radial bearing surface 21 of the sleeve are opposed to each other through a micro-gap. The micro-gap is filled with gas. On the radial bearing surface on the side of the stationary part, radial dynamic-pressure-generating groove rows are formed. In each row, a plurality of dynamic-pressure-generating grooves is arranged on the bearing surface in a circumferential direction. In the case of the structure shown in Fig. 1, two radial dynamic-pressure-generating groove rows 32 and 32 are formed apart in the axial direction. Each groove row constitutes the ra-

dial bearing, and two radial bearings support the rotary part 2.

[0035] The thrust bearing surface 13 of the stationary part 1 and the thrust bearing surface 23 of the rotary part 2 are opposed to each other through a micro-gap (Fig. 2). The micro-gap is filled with gas. On the thrust bearing surface 13 of the stationary part 1, a thrust dynamic-pressure-generating groove row 42 is formed. In the groove row, a plurality of dynamic-pressure-generating grooves is arranged on the bearing surface in the circumferential direction, thereby constituting the thrust bearing.

[0036] In Fig. 2, inclination of double lines 32b or 42b to bearing surface beside means that the dynamic-pressure-generating groove row generate a gas pressure difference on the bearing surface, and the gas pressure is increased at the separated end of the double line from the bearing surface comparing to the near end.

[0037] That is, in Fig. 2, the thrust dynamic-pressure-generating groove row 42 functions to increase the pressure of gas toward a annular micro-gap portion 102 between a gap of the radial bearing and a gap of the thrust bearing. Similarly, the radial dynamic-pressure-generating groove row 32 (not shown in Fig. 2) functions to increase the pressure

toward the annular micro-gap portion 102.

[0038] Here, the gap of the radial bearing and the gap of the thrust bearing are connected to each other over the entire periphery of the bearing, and the annular micro-gap portion 102 is also annularly formed. Gas filled in the micro-gaps can flow through the annular micro-gap portion.

[0039] At the time of rated rotation, the radial dynamic-pressure-generating groove row generates higher pressure difference than that generated by the thrust dynamic-pressure-generating groove row. So the gas filled in the micro-gap of the bearing tends to move toward the thrust bearing from the radial bearing. However, if this trend remains as it is, gas is lost from a region sandwiched between the two radial dynamic-pressure-generating groove rows 32 and 32, and there is an adverse possibility that the gas dynamic pressure bearing system operates abnormally. Therefore, the rotary part is formed with a communication passage 53. That is, the radial bearing supplies, through the communication passage 53, the gas deficiency on its side where the pressure of the bearing gap is lowered. At the time of rated rotation, gas which was lost from a space between the radial dynamic-pressure-generating groove rows is supplemented by gas

flowing through the communication passages 53b, 53c and 53a. This communication passage 53 is connected, through a peripheral space, to a side of the thrust bearing where a pressure of the bearing gap is lowered. When the bearing system starts rotating and stops rotating, a pressure difference which is generated by the thrust dynamic-pressure-generating groove row 42 becomes relatively higher than that generated by the radial dynamic-pressure-generating groove row 32. Therefore, the airflow passing through the communication passage 53 reversed.

[0040] Dust generated when the bearing surface comes into direct contact is mainly generated on the side of the thrust bearing. If the particle enters the radial bearing, the bearing surface is damaged and affected seriously. This is because that the micro-gap between the bearing surfaces of the radial bearing is smaller than that of the thrust bearing. At the time of rated rotation, the gas in the bearing flows from the radial bearing to the thrust bearing, and a centrifugal force is also applied. Therefore, the possibility that the particle generated in the thrust bearing enters the radial bearing is small. When the bearing system starts rotating and stops rotating, since gas may flow from the thrust bearing to the radial bearing in some cases, it is

necessary to catch the particles and to reduce the invasion of particles to the radial bearing.

[0041] The particle catching hole 100 is provided for this purpose. Fig. 5 is a plan view of the thrust plate 15. Fig. 5 shows the thrust dynamic-pressure-generating groove row 42 and the particle catching holes 100 formed by extending their grooves. In Fig. 5, however, the particle catching hole 100 is a groove and is not a hole. Since the thrust plate 15 is mounted on an end surface of the outer shaft 14b in the axial direction thereof, the opening of the groove structure 100 in Fig. 5 is closed by the outer shaft end surface and becomes the particle catching hole 100.

[0042] Since each the particle catching hole 100 opens adjacent an end 101 of the thrust dynamic-pressure-generating groove, particles in the thrust bearing is efficiently introduced into the hole and caught. Since the bearing on the side of the stationary part 1 is always formed with the particle catching hole, a centrifugal force caused by rotation is not applied to the caught particles, and the returning of particles into the bearing is very rare.

[0043] According to the gas dynamic pressure bearing system shown in Fig. 1, particles in the thrust bearing is effectively prevented from entering the radial bearing, lifetime

of the bearing system is increased and the reliability is enhanced. Since the particles are trapped, the possibility that the particles are discharged outside of the bearing system is reduced.

#### **MODIFICATION OF THE FIRST EMBODIMENT**

[0044] A modification of the first embodiment will be explained using Figs. 3, 4 and 6.

[0045] In Fig. 3, the particle catching hole is formed in an end of the outer shaft 14b instead of the thrust plate 15. Fig. 6 is a plan view of the particle catching hole. In this example also, the particle catching hole 100b is a groove before the thrust plate 15 is mounted on the outer shaft end. An opening of the groove is closed with the thrust plate 15, and the opening becomes the particle catching hole 100b.

[0046] According to the structure shown in Fig. 3, the end 101b of the thrust dynamic-pressure-generating groove row 42 is slightly extended toward the outer shaft 14b, and partially superposed with the particle catching hole 100b. With this configuration, particles in the thrust dynamic-pressure-generating groove are efficiently introduced into the particle catching hole. Among the dynamic-pressure-generating grooves which constitute the thrust dynamic-pressure-generating groove row 42, if only the dy-

dynamic-pressure-generating groove which is superposed with the particle catching hole 100b is extended, this effect can be obtained.

[0047] It is not always necessary to extend the end of the dynamic-pressure-generating groove 42, and the end may not be superposed with the particle catching hole 100b as shown in Fig. 4. Only if the opening of the particle catching hole and the end 101c of the thrust dynamic-pressure-generating groove row are opposed to each other, the effect for catching particles can be obtained. Among the dynamic-pressure-generating grooves which constitute the thrust dynamic-pressure-generating groove row 42, if only the dynamic-pressure-generating groove which is superposed with the particle catching hole 100c is opposed to the opening of the particle catching hole 100b, this effect can be obtained.

## **SECOND EMBODIMENT**

[0048] A second embodiment of the invention will be explained using Fig. 7.

[0049] Fig. 7 is a sectional view of a spindle motor 64 having a gas dynamic pressure bearing system 9 of the invention.

[0050] The gas dynamic pressure bearing system 9 includes radial dynamic-pressure-generating groove rows 32 and

32, and two radial bearings which are separated from each other in an extension direction of the shaft. The gas dynamic pressure bearing system 9 also includes thrust dynamic-pressure-generating groove rows 42 and 42 provided on two opposed thrust plates, and includes two thrust bearings which generate supporting forces in opposite directions. The double lines shown on the sleeve have the same meaning as those shown in Fig. 2. The dynamic-pressure-generating groove on the thrust bearing increases a pressure of air which lubricates the bearing surface toward the radial bearing. The dynamic-pressure-generating groove on the radial bearing increases a pressure of air which lubricates the bearing surface toward the thrust bearing.

[0051] A difference in pressure of air between the two radial bearings and air outside the thrust bearing generated by effect of the thrust and radial dynamic-pressure-generating grooves is overcome by providing the communication passage 53. One end 53a of the communication passage 53 is opened between the two radial bearings, and this point is the same as that of the gas dynamic pressure bearing shown in Fig. 1. On the other hand, the other ends 53b, 53b of the communication pas-



sage 53 are opened at upper and lower sides of the thrust plate. The communication passage 53 is formed in an inner shaft.

[0052] This configuration facilitates the working of the communication passage. This is because that since the inner shaft 14a has no portion that comes into direct slide, the communication passage can be made of normal metal material. On the other hand, the bearing surfaces of the outer shaft, the thrust plate and the sleeve must be made of ceramic having excellent wear resistance and high hardness. According to the structure of the communication passage shown in Fig. 7, since the centrifugal force is applied to particles generated in the thrust bearing, it is rare that a particles reaches the opening 53b of the communication passage. It is rare that the inside of the communication passage is contaminated by particles.

[0053] When a force is applied to the particles in the thrust bearing toward the radial bearing, the particles are caught by the particle catching holes which are continuously provided in the dynamic-pressure-generating groove 42, and the particles are prevented from entering the radial bearing.

[0054] In the spindle motor 64 having the gas dynamic pressure

bearing system, a recording disk 932 is placed on a hub 62 fitted over the sleeve 24. The shaft 14 is fixed to a base 63, and a stator 60 is mounted on the base. Rotor magnets 61 are arranged annularly on a lower portion of the hub 62. Magnetic poles of the magnets are opposed to the stator.

[0055] According to the spindle motor having the above-described structure, particles generated in the bearing are not discharged out from the bearing, and will soon be caught by the particles catching hole 100. Therefore, the reliability as a bearing system is high and the spindle motor does not discharge particles. Thus, this spindle motor is especially suitable for a hard disk drive which is required to rotate at high speed.

### **THIRD EMBODIMENT**

[0056] A third embodiment of the invention is shown in Fig. 8.

[0057] Fig. 8 shows a data storage disk drive 910 having a spindle motor of this invention.

[0058] In a housing 911 of the data storage disk drive 910, a recording disk 932 is mounted on the spindle motor 9, and a magnetic head 916 supported by a swing arm 915 is opposed to a surface of the disk 932 at a small distance

(micro-gap). When a particle enters the micro-gap, the particle injures the recording disk surface and the magnetic head, and reading and writing errors of information are caused. Therefore, particles should not exist in the housing 911.

[0059] When the spindle motor of the invention is used for the data storage disk drive, since it is difficult to discharge particles into the housing 911, the spindle motor can rotate at high speed, and the reliability of the data storage disk drive can be secured.

#### **FOURTH EMBODIMENT**

[0060] A fourth embodiment of the invention is shown in Fig. 9.

[0061] Fig. 9 shows a polygon scanner 940 having a spindle motor 64 of the invention.

[0062] In the spindle motor 64, a polygon mirror 960 is mounted on a hub 62, and the spindle motor rotates at high speed. The spindle motor 64 and the mirror 960 are accommodated in a housing 950, and the spindle motor 64 and the mirror 960 reflect light entering from a beam-permeable slit 952 of a side surface of a cover 950. The slit 952 is covered with a clear glass cover 953.

[0063] The spindle motor 64 includes the gas dynamic pressure

bearing system 9 of the invention, and the spindle motor has high bearing rigidity but has few troubles caused by generation of particles in the bearing system. The particle catching hole 100 is provided continuously with the thrust dynamic-pressure-generating groove row 42 and particles are trapped in the groove row. Therefore, particles enter the radial bearing surface and the bearing surface is not damaged.

[0064] The present invention is not limited to the above-explained embodiments. For example, although the dynamic-pressure-generating groove is illustrated on only one surface constituting the dynamic pressure gas bearing system in the drawings, the groove may be provided on the other surface which constitutes the dynamic pressure gas bearing system or may be provided on both the surfaces. Shapes of the dynamic-pressure-generating grooves are illustrated in the drawings corresponding to respective embodiments, but other shapes may be employed, and the same effect of the invention can be obtained. As shown in Figs. 2 and 7, each the dynamic-pressure-generating groove enhances a pressure of air which lubricates the bearing in a direction specified in the specification. Although air is used as the gas which lubri-

cates the bearing, gas other than air may be used only if the gas is noncorrosive gas.

[0065] Although the number of particle catching holes illustrated in Figs. 5 and 6 is four, the number is not limited to four. The number of the holes may be the same as the number of grooves in the thrust dynamic-pressure-generating groove row, or two particle catching holes may be formed for an opening of one thrust dynamic-pressure-generating groove. Even if the number of particle catching holes exceeds four, this does not depart from the scope of the invention.

[0066] The term "gap" in this specification will be explained. The gap in the specification means a gap between bearing surfaces in a state in which a gas dynamic pressure bearing system or a spindle motor rotates, a supporting force is generated by a thrust bearing and a radial bearing, and the bearing surfaces maintain the non-contact state. Therefore, when a product is checked when it is stopped, a gap can not be seen between the thrust bearing surfaces in some cases. Even in such a case, the bearing system has play so that a shaft body or a sleeve can float. Because this play exists, the bearing can rotate, and the gap is held between the bearing surfaces in a state where a suf-

ficient supporting force is generated. Even when no gap can be visually seen when the bearing stopped, if the bearing is seen at the molecular level, the bearing surfaces are in contact at extremely small portions. From this viewpoint, it can be considered that the gap spreads over substantially the entire regions of the opposed surfaces of the bearing.